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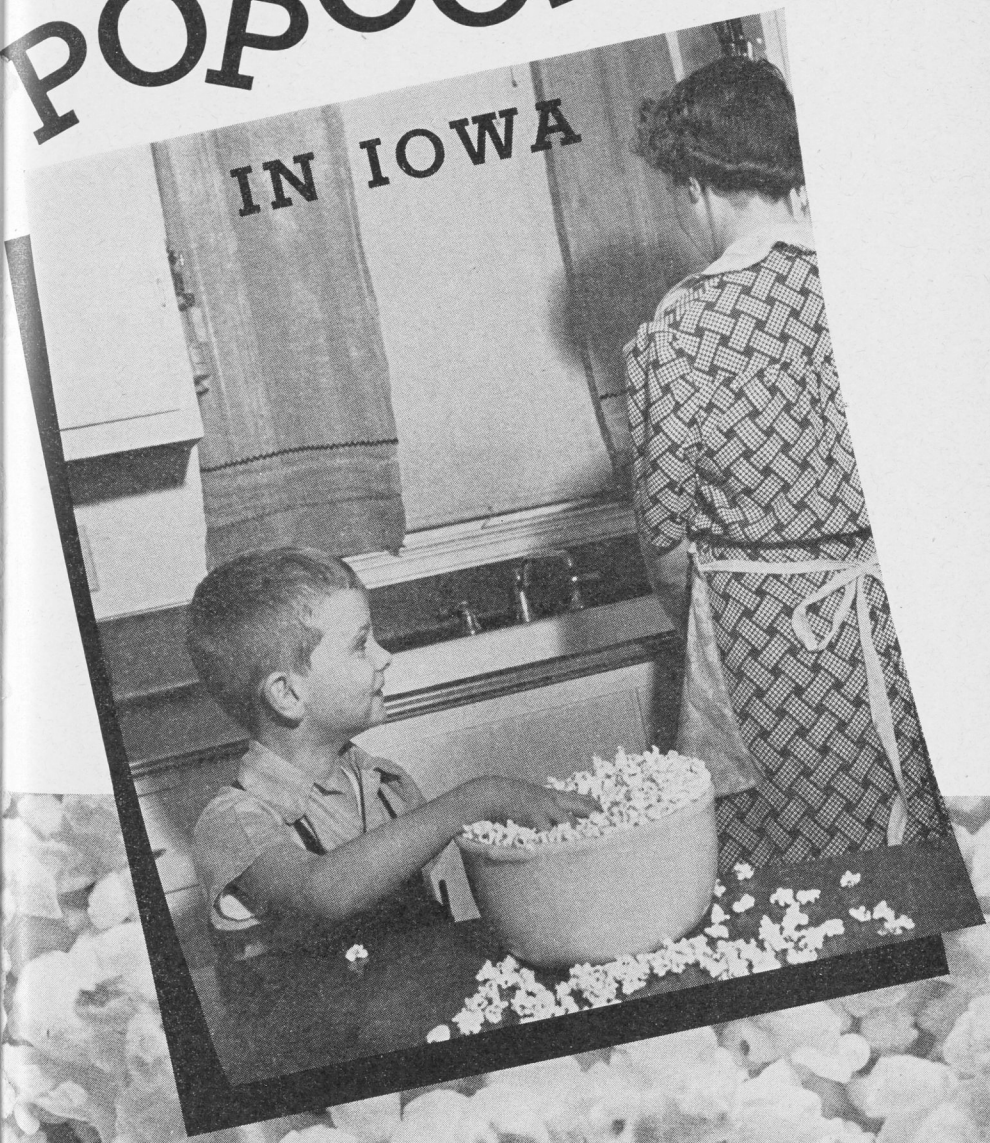
POPCORN IN IOWA



AGRICULTURAL EXPERIMENT STATION—AGRICULTURAL EXTENSION SERVICE, Cooperating
IOWA STATE COLLEGE AMES, IOWA

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Popcorn in Iowa

By J. C. Eldredge and P. J. Lyerly

The early history of popcorn is mostly a subject of speculation. It is reported to have been used by the natives of the Western Hemisphere before the coming of the white man. An old Chinese book in the Library of Congress, written in 1590, describes a type of maize, the kernels of which burst open when heated; however this could have referred to a type of maize other than popcorn, or even to sorghum, some types of which pop open when heated.

Our "early settlers" may have known and used popcorn, but a careful study of old farm papers, seed catalogs and premium lists reveals that they make no mention of popcorn until about 1880. Only in the last 50 or 60 years has popcorn developed as an important article of commerce in the United States. In the last decade there has been a still greater commercial expansion, due to the more extensive use of popcorn by stands, amusement parks, taverns and other resorts. In recent years several large companies have put popped corn on the market in cellophane bags and in tin or paper containers. This undoubtedly has greatly extended its use by family groups and others at parties and picnics.

Popcorn producers fall into two classes, those who produce the crop in the home garden or on a small acreage for home use, with the surplus sold to neighbors or to local stores, and those who produce the crop on a commercial basis. In the second group the crop is grown in large fields and is planted, cultivated and harvested with power machinery in most instances. To a certain extent the type of popcorn raised by the two groups is different. The home gardener is interested primarily in a variety that is tender and free from objectionable hulls and is not so concerned with high yield, high popping expansion or ease and rapidity of picking. The large commercial grower, while he cannot ignore eating quality and freedom from hulls, demands a high-yielding popcorn that will

stand up well until harvest and that can be picked satisfactorily with mechanical pickers. Popcorn distributors, who usually have their corn grown under contract, must have a corn which has a good appearance when popped and with a high popping expansion.

An ideal popcorn, therefore, should have the following qualities: (1) High popping expansion; (2) desirable eating qualities, including good flavor and freedom from coarse hulls; (3) good color, which includes freedom from the dark appearance found in the popped corn of some yellow varieties, caused by a dark-colored aleurone layer; (4) reasonably high yield; (5) stiff stalks which remain erect and hold the ears until harvested; and (6) freedom from disease.

DISTRIBUTION AND ACREAGE

Although unknown in many parts of the world popcorn is believed to be grown in every state in the Union as a garden crop to supply home needs. This home production represents a considerable part of the total acreage.

Until recently the commercial production of popcorn for vendors, makers of confections, and for general retail distribution was chiefly localized in Iowa, Kansas and Nebraska. These states grew about 70 percent of the crop. The almost complete failure of the crop in these commercial areas in 1934 and 1936 because of drouth and the ensuing high prices encouraged the rapid expansion of popcorn production in other localities, particularly in Illinois.

Iowa is easily the leading popcorn-producing state, with Illinois second; a considerable amount is also grown in Ohio, Michigan, Indiana, Kansas, California, Kentucky, Nebraska and Texas. The average popcorn acreage in these 10 states, which comprised most of the commercial acreage during the 4-year period, 1938-1941, was 54,390 acres; the average yield was 1,478 pounds of ear corn per acre. The total United States acreage in 1939 according to the 1940 census was 71,951 acres and the average yield 1,369 pounds. Government crop reports indicate an average of over 90,000 acres in 1941 and 1942.

The acreage, yield per acre, price for ear corn received by

TABLE 1. ACREAGE, YIELD PER ACRE, PRICE OF EAR CORN RECEIVED BY THE GROWERS, AND THE GROSS RETURN PER ACRE OF POPCORN IN IOWA FROM 1925 TO 1941.

Year	Acreage harvested	Yield per acre (lbs.)	Price per hundred (lbs.)	Gross return per acre
1925	54,100	1,685	$3.00	$50.55
1926	29,400	1,450	2.79	39.15
1927	17,500	1,665	2.50	40.62
1928	20,700	1,710	2.50	42.75
1929	26,300	1,525	2.80	42.70
1930	41,200	1,235	2.80	34.58
1931	19,400	1,230	2.00	24.60
1932	15,000	1,670	1.25	20.88
1933	6,700	1,700	1.00	17.00
1934	12,400	415	5.00	20.75
1935	35,000	1,200	2.10	25.20
1936	13,400	360	4.00	14.40
1937	21,200	1,135	1.75	19.86
1938	20,200	1,530	1.30	19.89
1939	20,900	1,560	1.20	18.72
1940	21,000	1,600	1.25	20.00
1941	40,200	1,300	2.00	26.00

producers, and the gross return per acre of popcorn in Iowa from 1925-1941 are shown in table 1. The average number of acres during this 17-year period was 23,788 and the average acre yield 1,363 pounds. Wide fluctuations in yearly acreage, production and price are evident. Sac and Ida counties, located in west-central Iowa, have been the center of commercial production in this state. Sac County produces more popcorn than any other county in the United States. Other counties in the approximate order of their importance are Clay, Crawford, Calhoun and Carroll. Fremont County in southwestern Iowa has had a considerable acreage in very recent years.

Little is known of the production of popcorn in other countries, except Argentina, from which over a million pounds was exported both in 1936 and in 1937.

Profit in producing popcorn depends on the ability of the growers to produce a crop of good quality, cure and store it properly and market it advantageously. Compared to dent corn, popcorn is more difficult to produce, harder to obtain stands, more troublesome to keep clean and much more arduous to harvest, store and deliver. Marketing difficulties and

fluctuating prices often make it an unprofitable crop for growers inexperienced in popcorn production. Only twice since 1930 has popcorn given as large a gross return per acre as a 50-bushel crop of dent corn at 50 cents per bushel (table 1), and growing costs usually are greater for popcorn than for dent corn.

The supply of popcorn fluctuates widely from year to year. Following an unfavorable season with low yields, prices on the retail market often go to 8 and 10 cents per pound, and inexperienced persons, thinking they see a chance to make money in popcorn, rush into production. Since the demand is rather inelastic, the result is a glutted market, and these amateur growers often cannot sell their corn at any price, much less at a profit.

VARIETIES

Popcorn varieties may be divided into three main groups on the basis of kernel and ear type: Rice, Pearl and Japanese Hulless. (The variety Japanese Hulless, or Jap Hulless as it is often called, did not originate in Japan.) The rice type has a sharp pointed kernel, often ending in a hook or beak. The pearl type has a short, thick kernel which is round at the crown and may be either white or yellow. The Japanese Hulless has a distinct, long, slender, shoepeg kernel which may have either a pointed or a round crown. The ears are characteristically short and thick, and the kernels are not in distinct rows on the cob. There are dozens of varieties and strains listed by seedsmen, the same variety frequently being offered under several names by different dealers.

What variety of popcorn is best is a question frequently asked. The best variety depends on individual preference, the local market demand and other factors. Some localities or individuals prefer the small kerneled Japanese Hulless type while others want the large, yellow pearl type. The distributors in the popcorn-producing area of northwest Iowa demand the large kernel yellow type, especially for the eastern market. In order to assist the grower in choosing a suitable variety several varieties are described. Table 2 gives data on eight varieties included in a yield test continued through a 5-year period at Ames.

TABLE 2. YIELD, POPPING VOLUME AND PERCENTAGE OF MOISTURE AT HARVEST (RELATIVE MATURITY) OF EIGHT VARIETIES OF POPCORN TESTED AT THE IOWA AGRICULTURAL EXPERIMENT STATION DURING THE 5 YEARS, 1932, '33, '35, '36 and '37.

Variety	Yield; lbs. shelled corn per acre	Average popping expansion	Percent moisture at harvest
Japanese Hulless	1606	20.4	17.8
White Rice	2472	17.2	18.5
Spanish	1790	14.5	13.3
South American	2288	17.6	22.6
Yellow Pearl	2144	20.4	20.4
Supergold	2345	22.6	22.6
Superb (2-yrs. only)	2130	19.2	13.3
Tom Thumb (3-yrs. only)	1865	20.1	26.0

Japanese Hulless or Dwarf Rice (now being listed as White Hulless by the large popcorn distributors), the most popular white variety, has a short chunky ear with slender, white, shoepeg-type kernels. It has reasonably high popping expansion and gives a tender popped kernel free from hulls. This variety is excellent for home use and popcorn stands, but is too tender for use for Karmel corn. It is rather early and is adapted to the northern half of the Corn Belt—from central Iowa north—but is only moderately adapted to southern Iowa and is difficult to produce successfully south of Iowa and Nebraska.

White Rice was the most popular popcorn 20 years ago and is still grown to a considerable extent in the east but has nearly disappeared in recent years in the important popcorn areas of Iowa. It has a rather low popping expansion, rather coarse hulls and a coase-textured popped kernel without a distinctive flavor. The ear is relatively large and yields are generally high. The kernel is broad and somewhat flattened with a very sharp pointed crown. This variety seems to have a very wide range of adaptation.

Queen's Golden has a long, slender ear with medium-sized, yellow, pearl-type kernels, only medium popping expansion, medium in tenderness and freedom from hulls. It is fairly late maturing and not safe for northern Iowa. Queen's Golden is not popular in the commercial popcorn areas.

Yellow Pearl is really a type name for all yellow varieties

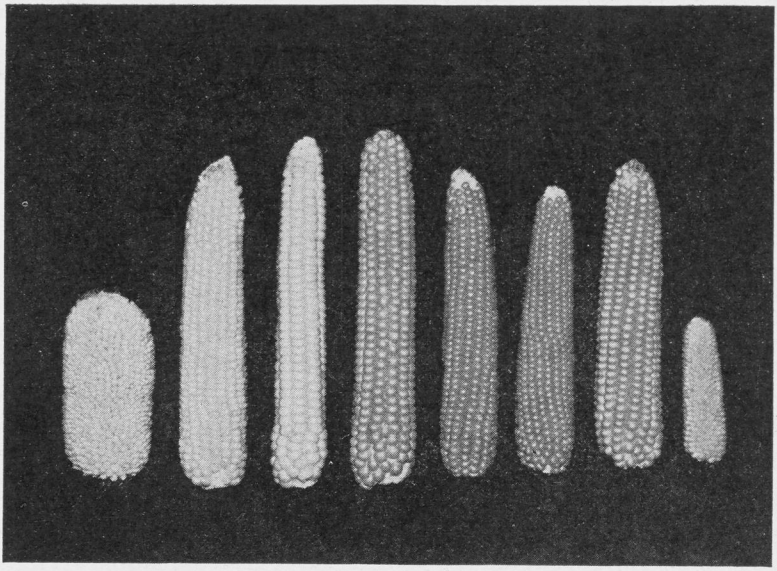

Fig. 1. Popcorn varieties. Left to right—Japanese Hulless, White Rice, Spanish, South American, Yellow Pearl, Supergold, Superb, Tom Thumb.

having pearl-type kernels, but the name also has been applied to a distinct variety. The ear is of medium length and distinctly pointed, with medium to small kernels deep yellow in color. This variety has a medium high popping expansion, is fairly free from coarse hulls and is early enough to be safe in northern Iowa. It is much more desirable than Queen's Golden.

Supergold, originally introduced by the Kansas Experiment Station as Sunburst, was developed by Dr. A. M. Brunson, agronomist of the United States Department of Agriculture, by ear-to-row selection for high popping volume. Supergold has a slightly less pointed ear than Yellow Pearl and somewhat larger kernels, which are deep yellow in color. The popping expansion is high, and the popped corn is relatively free from coarse hulls and does not have a very decided flavor. This variety is early enough to be relatively safe in Iowa, except possibly in the extreme northern part of the state.

South American, also called "Dynamite," "Mushroom" and

several other names, is a yellow pearl type which first appeared around Kansas City a few years ago. It originally was supposed to have come from Argentina but probably did not. Ears are medium in length and have very large, round, medium yellow kernels, which when popped have a distinct yellow color. The popped kernel is very large, with a coarse, heavy hull, and a distinctive flavor much favored by some but not by others. It is a late variety, not safe north of central Iowa, and is best adapted in Kansas, Missouri and the South.

Superb, or Superb South American, is a yellow pearl type having a medium thick, medium short ear, with a large, pale yellow kernel. When popped it gives a very large, pale yellow product with rather coarse hulls and distinctive flavor. It is considerably earlier than South American and can be grown safely in north-central Iowa. This corn is proving popular with the large commercial distributors in northwest Iowa. Superb has a distinct weakness, however, in that the stalks break rather badly before harvest.

Spanish or Eight Row is a white pearl type with a slender, medium length ear, bearing very large kernels. It has a rather poor popping expansion and produces a tough, coarse, popped product with very heavy hulls. Spanish is extremely early and must be planted later or picked promptly when ripe or the stalks will fall over and the ears become damaged. The stalk is very short with the ears borne close to the ground.

Tom Thumb is a name applied to several distinctly different, small-eared types. Brunson has described the variety as very early with a blunt ear, bearing pearl-type, yellow kernels. The corn tested at the Iowa Agricultural Experiment Station under this variety name is extremely late, with very small, slender ears bearing distinctly rice-type, small, yellow kernels. Tom Thumb suckers profusely, and each stalk bears several ears, so that the yield is large, but the crop very difficult to harvest. When popped the kernels produce a small, very tender product, without hull and have a characteristic flavor much liked by some. Another Tom Thumb, also called Australian Hulless, has pale yellow, pearl-type kernels borne on small, very slender ears. It is also extremely late in maturity, suckers profusely and has many ears per stalk.

The data in table 2 show that there are considerable differences in acre yield and in popping expansion among the varieties. The percentage of moisture at harvest time indicates the relative maturity. Since these yields are higher than ordinarily would be obtained under commercial conditions, the data from table 1 should be used in comparing the relative productivity of popcorn and dent corn under farm conditions.

In an attempt to study the characteristics of popcorn preferred by consumers, staff members and students at Iowa State College were asked at various times to compare, in an "eating test," the eight varieties listed. They were asked to rate each sample on (1) flavor, (2) coarseness of hull and (3) tenderness. In rating on flavor a majority (about 75 percent) preferred the flavor of the Jap Hulless and Tom Thumb while the remainder preferred the large, yellow varieties. On freedom from hulls and tenderness a large majority rated the Jap Hulless and Tom Thumb best. Even those who preferred the flavor of the yellow varieties agreed that they were not as tender or as free from hulls as the others. The White Rice and Spanish almost invariably were rated poorest since they have a heavy hull, a coarse texture and no distinctive flavor.

In another series of tests in which Japanese Hulless was compared over a period of several weeks with a mixture of the yellow pearl varieties, the samplers were asked to indicate their preference between the white or yellow kinds. In this test 51 percent chose the Jap Hulless and 49 percent the large yellow.

COLOR IN POPCORN

There are several kinds of red and purple popcorn. In general these are merely color variations of some standard variety. The red color of corn is carried either in the pericarp or in the aleurone (the outer coat of the endosperm just beneath the hull), while the purple color, called blue or black in some corn varieties, is carried only in the aleurone. By crossing varieties, for example, Jap Hulless with Red Rice, and selecting Jap-type ears with red color, one could develop a red, Jap-type strain. It in all probability would be a less tender strain unless rigid selection for tenderness was practiced. Yeager lists 11 so-called varieties of popcorn, among which are Black

Beauty and Black Diamond, both purple colored, yet Black Beauty has a relatively high popping expansion while Black Diamond is low. Red and blue popcorns are white after they are popped, but the dark-colored hulls or aluerone give the popped corn an unattractive appearance.

CULTURAL METHODS

With a few modifications, the methods employed in growing a crop of popcorn are the same as for field corn. Probably the greatest difference is the problem of weed control. Since popcorn seed is much smaller than dent corn and grows more slowly at first, early cultivation is more difficult, and weeds are apt to get ahead of the corn.

SEED

Popcorn seed should be carefully field selected before freezing weather, thoroughly dried and stored in a dry place to insure satisfactory germination. Much can be done to maintain and even increase the popping expansion of the harvested crop if the kernels from each ear are examined carefully and only ears used for seed which have a minimum of soft starch. As discussed elsewhere in this bulletin, there is a high correlation between popping expansion and the percentage of hard, flinty starch. Field selection of the ear is desirable to avoid picking seed from weak, diseased stalks, and also to maintain the desired stalk type.

Popcorn crosses readily with other types of corn, such as sweet and dent. This does not seem to affect the popping expansion or eating quality the year the cross occurs. In other words, the corn from a field of popcorn alongside a field of dent corn which is shedding pollen at the same time would pop satisfactorily. This outcrossed corn should not be used for seed because even if the ears from the outcrossed plants resulting are discarded in the commercial crop, their tassels would have shed pollen and thus contaminated many kernels. A popcorn variety may thus become badly mixed with dent corn with a consequent lowering of its popping expansion. Some operators of large chains of popcorn stands refuse to buy popcorn from local gardeners and amateur growers even at a much lower price because of the danger of this mixture with

dent or sweet corn. They will pay more to large popcorn distributors to insure a higher popping expansion due to higher quality seed and better processing methods.

SOIL

Any good corn soil can be used for popcorn. The crop naturally does better on the more fertile, heavier soils than on light, sandy soils, but probably will yield as well in proportion as will field corn on the same soil. Since it is desirable to start the crop off as rapidly as possible, as an aid in cultivation barnyard manure is decidedly beneficial. Recommendations for the use of commercial fertilizer are similar to those for field corn except that the use of a complete fertilizer containing nitrogen, to obtain the quick start in the spring, is probably desirable. For average to good soils a fertilizer containing 2 percent nitrogen, 12 percent phosphorus and 6 percent potash is recommended. This is known as a 2-12-6 fertilizer. For poorer soils a 4-16-4 fertilizer is probably desirable.

In order to determine whether the use of commercial fertilizer had any effect on the popping expansion or eating quality of popcorn an extensive test was conducted for two seasons on five varieties, Jap Hulless, White Rice, South American, Superb and Pinkie. This gives a range of early, medium and late varieties. Four different plots were given a heavy application of fertilizer as follows: Plot No. 1 superphosphate, No. 2 potash, No. 3 nitrogen and No. 4 complete fertilizer. Each of the five varieties was grown on each plot and also on an adjacent check plot which had received no fertilizer. None of the fertilizer treatments had any effect on popping expansion or eating quality.

THE SEEDBED

The seedbed should be prepared the same as for field corn, but it is even more important that it be firm and mellow, free from coarse clods and with moisture near the surface, so that deep planting is not necessary.

PLANTING

Planting, particularly of the early varieties, can be delayed until after the field corn is planted, thus giving a longer time

for weed seed to sprout and be killed. Popcorn usually is check-rowed to facilitate weed control but on clean ground may be drilled. Planter plates for popcorn can be obtained for most makes of planters, or sorghum plates may be used. The rate of planting should be heavier than for field corn—four or five kernels per hill for the larger varieties and five or six for Jap Hulless. It requires from three to seven pounds of seed to plant an acre, depending on the size of seed and rate of planting. Jap Hulless requires from three to five pounds and the larger kerneled varieties four to seven pounds per acre.

CULTIVATING

Cultivation of popcorn, like field corn, is primarily for weed control, and good cultivation practices apply the same to each. The more weeds that can be killed before planting the better.

DISEASES AND INSECTS

Diseases and insects attacking popcorn are the same as those of field corn. Smut is common, some varieties being more susceptible than others. The ear, stalk and root rots all attack popcorn and are especially serious because in most instances they affect some of the ears, either directly or by causing the stalks to break over, bringing the ear into contact with the ground. These moldy, diseased ears, unless carefully sorted out, result in discolored kernels in the shelled corn, spoiling its appearance and greatly lowering the popping expansion and palatability of the popped product. Most of these diseases are difficult to control, but careful seed selection, resistant strains and crop rotation will help. Careful sorting before shelling will result in a higher quality of corn for popping.

One of the worst insects attacking popcorn is the corn ear worm. It is especially bad on the Jap Hulless as it seems to find easy access into the thick, blunt ears of this variety. Much damage is done during outbreaks of this pest, not only from direct injury by the worm but also by the molds that so often develop around the areas damaged. Unfortunately, there are no practical control measures. Other insects such as root worm, root aphis, chinch bugs and grasshoppers attack

popcorn as readily as field corn. Severe chinch bug injury may seriously affect the popping volume by causing starchy, shriveled kernels. Stored-grain insects such as the Angumois grain moth and the brown grain weevil attack popcorn, especially when it is carried over several years. Small quantities of popcorn which can be placed in airtight cans or tanks can be treated with carbon bisulfide without any disagreeable flavor resulting. Avoid fumigants such as paradichlorobenzine which impart an undesirable flavor. The vapors of many common fumigants apparently affect the permeability of the seed coat temporarily and prevent maximum expansion. The effect of the treatment may persist as long as a week or two in some cases but usually disappears entirely after 30 days.

HARVESTING

Popcorn, because of the small size of the ears, is much more tedious to harvest by hand than is field corn. Experienced huskers often prefer to pick dent corn even where they could earn more by picking popcorn. Much of the popcorn is snapped rather than husked as the husks help protect the kernels from dust, dirt and insects while in storage and also help to keep the moisture content more uniform during hot, dry periods in the summer. Snapping is much easier and faster than husking when the crop is harvested by hand.

Much of the popcorn in the large producing areas is picked with machines. Most makes of mechanical huskers can be adjusted so that they will pick popcorn satisfactorily. The rolls must be set close together and if the corn is to be snapped the husking rolls are covered or removed. Some picker manufacturers are putting out special attachments designed for harvesting popcorn.

It is best to delay harvesting popcorn until it has cured as much as possible on the stalk but not so long that it is injured by wet fall weather or by the stalks falling over, resulting in the ears coming into contact with the soil. The crop should always be allowed to mature fully, or be left until frost has killed the stalks, because immature popcorn may have a lowered popping expansion.

In some of the eastern states popcorn is cut and shocked

and the ears allowed to cure in the shock. It is later husked out by hand or put through a corn shredder. The California Experiment Station has been working on the problem of combine harvesting of popcorn. By using the very small prolific types such as Tom Thumb, planted thick and permitted to cure thoroughly on the stalk, combining may prove successful, especially in dry climates.

FACTORS AFFECTING POPPING EXPANSION

Popping expansion is determined by the relative percent and location of hard and soft starch in the kernel and the proper moisture content. Although popping is not restricted to popcorn, it finds its greatest expression in this form of maize, which is almost entirely of a hard, flinty nature, containing very little soft starch. Good flint corn will pop to a certain extent and kernels of hard dent varieties will pop slightly. Some hard, flinty grain sorghums will pop well; Indians have been known to pop the small, shiny seeds of pigweed. Large differences in poppability exist among varieties of popcorn, as already shown.

Popping of popcorn is believed to be due to the sudden liberation of pressure, created by steam confined within the kernel, until an explosive force is reached. This steam is derived from the moisture of the kernel when heated. Apparently the softer types of corn permit the gradual escape of the steam so that there is not enough pressure to cause the sudden explosion necessary for complete popping.

Popping expansion, or popping volume as it is sometimes called, is measured as units of popped corn obtained from one unit of unpopped corn. For example, if 100 cc. of unpopped corn gives 2,400 cc. of popped corn, the sample is said to have a popping expansion of 24. A large expansion is very desirable. The operators of commercial popcorn establishments desire a large expansion since their produce is sold on a volume rather than on a weight basis. Fortunately, also, a high popping expansion seems to be associated with palatability. since the larger, lighter and fluffier popped kernels usually are the tenderer.

Of the factors affecting the popping expansion of a variety,

TABLE 3. POPPING EXPANSION OF DIFFERENT LOTS OF POPCORN PURCHASED FROM GROCERY STORES IN AMES, IOWA, ON APRIL 13 AND JUNE 12, 1939.

Date purchased	Store	Popping expansion		Volumes increased	Percent increase
		As purchased	Brought to optimum moisture		
April 13	1	5.7	11.7	6.0	105
	2	7.4	15.0	7.6	103
	3	11.8	20.3	8.5	72
	4	17.2	18.6	1.4	8
	5	12.8	20.0	7.2	56
	6	20.7	20.9	.2	1
	7	15.4	22.6	7.2	47
	8	15.2	17.2	2.0	13
	9	19.2	21.8	2.6	14
June 12	4	17.8	19.5	1.7	10
	6	18.1	19.6	1.5	8
	7	17.6	20.2	2.6	15
	10	17.5	23.3	5.8	33
Average		15.1	19.3	4.2	38

ture proof or else the corn was too dry when bagged. Several commercial companies are putting corn into sealed cans, containing from eight to 16 ounces, in which the proper moisture content is retained almost indefinitely.

Frequently the question is asked whether popcorn loses its quality with age. Contrary to popular opinion, popcorn does not lose its popping expansion with age, but only through loss of moisture, or by insect or rodent damage or perhaps by mold if kept too damp. Corn properly stored through a 14-year period was found to have deteriorated only slightly in popping expansion. A slightly stale or rancid taste occasionally may be detected in corn five or six years old.

Since high popping expansion is dependent upon a large percentage of hard and vitreous starch in the kernels as well as the correct moisture percentage, it follows that any condition which causes an increase in soft starch will decrease quality. Excess soft starch with a resulting poor popping expansion is commonly caused by immaturity. Freezing before the corn is mature is most certain to injure quality.

The question often arises whether or not mechanical shelling injures popping quality. Tests have shown that machine shelling will not affect expansion if the corn is dry enough to

shell free of excessive chaff. Shelling and cleaning, if carried on in heated buildings with low humidity, might dry the corn too much if it is already low in moisture.

STORING POPCORN

Cribs for popcorn are designed to facilitate rapid and uniform drying. They are narrower than ordinary corn cribs and built to prevent rain from beating in. Cribs 3 to 4 feet wide can be expected to provide sufficient ventilation. If wider cribs are used partitions or airways should be built down the middle.

Since popcorn is used entirely for human consumption, construction which will keep out mice and rats is particularly desirable. This can be accomplished by the use of heavy screen wire on the floor and along the sides at the bottom with an 8- or 10-inch strip of galvanized sheet metal above the wire. Putting the crib on piers which are covered with metal to prevent entrance of rats and mice also is recommended.

Bulk popcorn usually is stored on the ear since there is less danger of its going out of condition when stored in this way. Most commercial distributors in fact prefer not to have the corn shelled very long before using. Popcorn should not be shelled until it is at the correct moisture content because the excess cob chaff which adheres to the kernel when shelled too moist is very objectionable.

For the drying and storage of popcorn for the home, or in limited quantities, screened crates are satisfactory. If mouse-proof, they can be placed in any airy building such as a garage or machine shed. Where mice and sparrows can be kept out, coarse mesh sacks, such as are used for potatoes or onions, hung from the rafters are satisfactory. Storage in an attic or spare room in the house is sometimes advised, but unless well ventilated, the corn may dry too slowly and later in the season is likely to become too dry, especially if artificial heat can reach the room.

STORAGE EXPERIMENTS

It usually is assumed that popcorn stored where the outside air can pass freely around it, as in cribs or crates in an airy shed, would remain in satisfactory popping condition the year

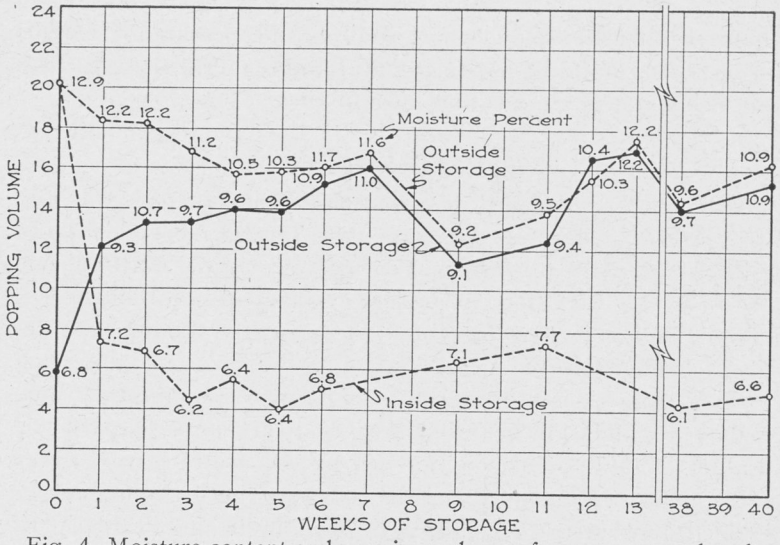

Fig. 4. Moisture content and popping volume of popcorn stored under outdoor humidity and temperature conditions and in a steam-heated room from March 17, 1939, to December 15, 1939.

round. Only infrequently has it been reported that corn so stored has become too dry and gone out of condition. Such was the experience of some growers in the drouth summers of 1934 and 1936.

To study the effect of natural temperature and humidity on the moisture content and popping expansion, in March, 1939, small samples of Japanese Hulless popcorn with a moisture content of 12.9 percent were hung in a screened crate subject to outdoor humidity and temperature conditions but protected from rain and direct sunshine. At the same time samples of the same corn also were placed in a steam-heated office room where humidity and temperature conditions were such as might be found in the average home or store. Samples from the same lot of Japanese Hulless popcorn, which had been dried down to 6.8 percent moisture, were also placed in the screened box outside. At weekly intervals from March until December duplicate samples were taken for moisture determination and popping tests. The results from this experiment are presented in fig. 4. The popcorn had a maximum expansion of about 20 volumes when its moisture content was optimum.

A second test extended from Feb. 29, 1940, to June 22, 1941. Approximately half-pound lots of Japanese Hulless popcorn, which had been stored inside for over a year and contained 8 percent moisture, were placed under the same outside conditions as mentioned above. Samples were removed at weekly intervals for popping and moisture determinations. The weekly rainfall, moisture percent and popping expansion are given in fig. 5.

It can be observed that: (1) Corn with the optimum moisture content became so dry within a week when stored in a heated room that it was unfit for popping. (2) When shelled and stored in small lots under natural atmospheric conditions of humidity and temperature, the moisture and popping expansion fluctuated rather rapidly. (3) Contrary to popular belief these samples did not remain in good popping condition when stored under natural atmospheric conditions.

Under conditions of this test a popcorn with a maximum expansion of about 23 volumes would average about 19 volumes. While a popping expansion of 19 volumes is considerably below maximum and unsatisfactory to the commercial popper, it probably would be quite satisfactory for home use and in as good or better condition than much of the corn

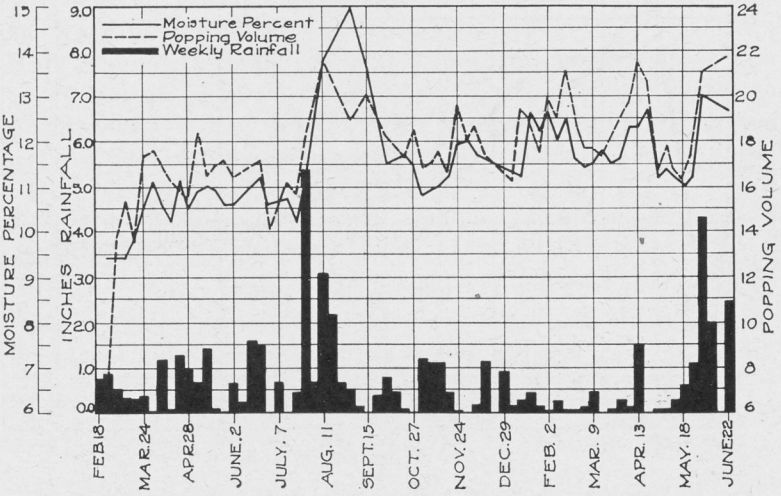

Fig. 5. Moisture content and popping volume of popcorn stored under natural atmospheric conditions from February 20, 1940, to June 22, 1941. Weekly rainfall also is shown.

purchased at stores. While the results from these tests will apply to small lots of corn stored for home use they are not typical of conditions where corn is stored in large quantities. Where stored in cribs on the ear the corn would be much less subject to fluctuations in humidity. Commercial growers find that under average Iowa conditions bulk ear corn will remain in reasonably satisfactory condition throughout most of the year, becoming too dry only during excessively hot, dry periods.

KEEPING POPCORN INDOORS

Few people realize how rapidly popcorn will dry out when exposed to the air in the average home in winter. Shelled corn in the cupboard in open containers or in paper bags dries out rapidly, especially during the winter when the humidity in heated rooms usually is low. As previously discussed, grocery stores often allow the popcorn they sell to become too dry. Many complaints are received from people who say that popcorn which popped well when first purchased soon become unpoppable and they wonder what the trouble is. In most instances the corn simply has become too dry.

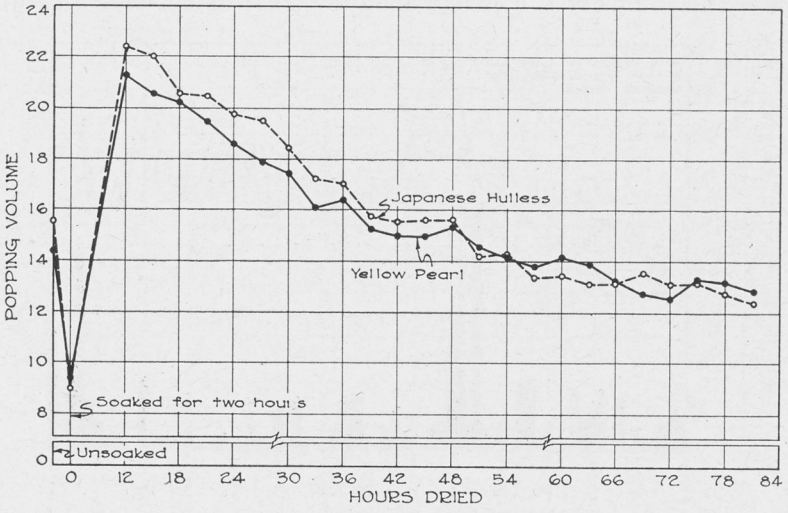

Fig. 6. Popping volume of Yellow Pearl and Japanese Hulless popcorn dried at room temperature for various intervals after soaking for two hours.

In another experiment popcorn containing about 9.5 percent moisture was soaked for 2 hours, which made it too wet for popping. Small samples both of Japanese Hulless and Yellow Pearl were spread on a table in a steam-heated office room with a temperature of 70 degrees and relative humidity of 35 percent. These conditions are typical of homes and other heated buildings in the winter. After a lapse of 12 hours samples were taken at 3-hour intervals for popping tests. The results are shown in fig. 6. With 2 hours' soaking the moisture had increased to 21 percent, resulting in a decrease in expansion to 9 volumes. Optimum expansion had been reached after 12 hours' drying, after which there was a steady decrease to about 12 volumes at the end of 81 hours. This indicates that corn in open containers in an ordinary room or kitchen cupboard during the winter months might be expected to lose its maximum popping expansion, due to drying, in 2 or 3 days.

CONDITIONING POPCORN

Many people do not realize that popcorn can be brought back into popping condition after it has become too dry to pop well. Commercial distributors have humidity chambers or other specially designed equipment for conditioning corn. For small quantities, water can be added directly to popcorn in a fruit jar or coffee can. A tablespoonful or two of water to a quart of corn should be sufficient. The amount of water to add depends on how dry the corn is, and this can be estimated by the way the corn pops. The corn must be thoroughly stirred as soon as the water is added in order to insure uniform distribution. Close the container tightly and let stand a few days until the moisture has had time to penetrate the kernels. Adding water and popping at once does not give satisfactory results. For moistening large amounts various methods may be employed. If screen bottom trays are available the corn can be soaked for a few minutes and spread in a 3- or 4-inch layer in any airy place for a few days. Or it can be spread on a clean floor or large table in a thin layer and stirred occasionally so that all the corn will dry uniformly.

If not too dry corn can be spread out, sprinkled lightly and

then after mixing, sacked up at once. If the surplus moisture dries into the corn in an hour or so it probably is dry enough to keep without exposing to the air.

Home supplies of popcorn kept in a heated room should be stored in tight containers. Better yet, place in the refrigerator or a cool basement. Some basements may become too damp during rainy periods in the summer, and the corn may mold if not kept in a tight container.

When in doubt as to whether corn is too dry or not dry enough the following test should give the answer. Carefully measure out two equal-sized samples of corn. Soak one for 20-25 minutes, dry off the surplus water and spread in a thin layer in a cool place, such as the unheated part of the basement in winter or screened porch in mild weather, for 15 to 20 hours. Spread the other sample, without soaking, in a thin layer in a heated room for 12 to 20 hours. Then, after popping a sample of the original corn to get the popper to working properly, pop a measured sample of the original corn, the soaked corn and the dried corn, and compare the results. This should tell whether the corn was too wet or too dry, or, if none of the samples pop well, that there was some other reason, such as immaturity or poor variety.

Popcorn vendors can test the popping expansion of their corn by popping a measured amount and measuring the popped corn in a container which has been calibrated in units of the unpopped corn. By regularly testing the expansion they can determine whether their supply of corn is being kept at the proper moisture content for maximum expansion.

When popcorn is dirty or contains damaged kernels, owing to ear worms or to shelling diseased ears with good ones, it can be improved greatly by washing. Put 8-10 pounds of corn in an ordinary pail and fill the pail with water. Stir violently and while the water is still swirling skim off the lighter, damaged kernels floating toward the surface. Pour off the dirty water and repeat the process several times until the water is clear. After the corn is thoroughly washed spread it in a rather thin layer on a window screen or screen bottom tray and allow to stand for several days in a cool, airy place to dry. If spread on an outside porch or similar place it can be left a week or more in mild weather. If spread in a fairly

dry basement or a room in the house it should be dry enough to store in 2 or 3 days.

ARTIFICIAL DRYING

Under Iowa conditions corn is seldom dry enough for popping when harvested. The ensuing winter months are unfavorable for drying, and popcorn usually does not come into popping condition before May or June. This means that in most seasons the crop cannot be put on the winter market the season it is grown but must be held over until the following year.

Artificial drying, if a successful system could be developed, would enable the grower to market the crop during the months immediately following harvest and thus eliminate the need for storage of the current and previous crop.

Experimental work on artificial drying of popcorn has been continued at Iowa State College for several years. The results, in general, have not been entirely satisfactory and in none of the experiments has a lot of corn taken directly from the drier given a satisfactory expansion. Although moisture determinations indicated that the average moisture was optimum, considerable variation occurred between individual ears; some were too wet while others were too dry. A period of time must be allowed for the moisture to become equally distributed throughout the entire lot of corn. This usually requires several weeks. In spite of this limitation it would seem that popcorn might be reduced to a correct moisture for early market with the aid of artificial drying. Care must be taken not to reduce the moisture below the minimum required for optimum popping.

POPPING CORN

There are many methods of popping corn, some of which are more successful and give a more palatable product than others. Types of poppers range from the small wire hand popper to be used over glowing coals to the large commercial electric units. Any cooking utensil, such as a covered frying pan or saucepan, may be successfully used, especially if some fat or oil is added. A medium deep saucepan with a handle is much less clumsy to use than a frying pan. Regardless of the type used it is important that the popper be at the right

temperature. If the corn is popped too slowly some of the moisture will escape before popping begins and maximum expansion will not be obtained. Likewise expansion may be low if the popper is too hot because the kernels scorch and do not become uniformly heated. Small electric poppers usually are satisfactory, although some types do not have a large enough heating element to provide adequate temperatures. To avoid scorching the kernels on one side, it is necessary to stir the corn during the popping process, especially if no fat is used in the popper. Although this can be accomplished by shaking the popper, a stirring rod operated by a crank is much more satisfactory. Popcorn may be popped dry, or with corn oil, lard, bacon fat, butter or commercial seasoning. There usually is less danger of scorching the corn or having the corn pop poorly if some fat is used to insure a more even distribution of heat around the kernels. The amount should be approximately 10 percent of the volume of unpopped corn although an excess of fat or oil will do no harm. This results in some increase in expansion and also reduces the time required for the kernels to pop. If salt is added to the popper a very fine grade, as used by popcorn stands, is much more satisfactory than ordinary table salt. The fine salt seems to penetrate the popped kernels and gives a better flavor. Properly cured popcorn with a uniform moisture content should start and finish popping rather uniformly.

Probably more people prefer plain, so-called "buttered popcorn" than any other form, but there are many recipes for using popcorn in other ways. Some enjoy popcorn and milk, used like prepared breakfast food. Most cook books contain recipes for those who wish to prepare popcorn confections.

POPCORN IMPROVEMENT

As previously mentioned, the ideal popcorn should have high popping expansion, be tender and free from coarse hulls and have a good flavor. From the standpoint of the grower it should be high yielding, stiff stalked, disease resistant and sufficiently early to mature fully in the locality where grown.

The grower can make some progress by selecting seed of a desirable variety from parts of the field farthest removed from other corn and by using only the best type ears for seed.

Much greater improvement is possible, however, by using the modern method of hybridization of inbred lines which has been so successful with field corn. The principals and techniques developed for the production, selection and testing of dent corn inbred lines and hybrids are equally applicable to popcorn.

Development of hybrid popcorn is necessarily more difficult than with dent corn because several additional characters must be included in a satisfactory hybrid. Good popping expansion is one of the most important and most difficult to obtain. In most cases the highest yielding, most vigorous hybrids are low in popping expansion. Considerable progress has been made at the corn belt stations which are working with hybrid popcorn, and the consumer can look forward to better eating popcorns and the grower to greater profits from the higher yielding hybrids.

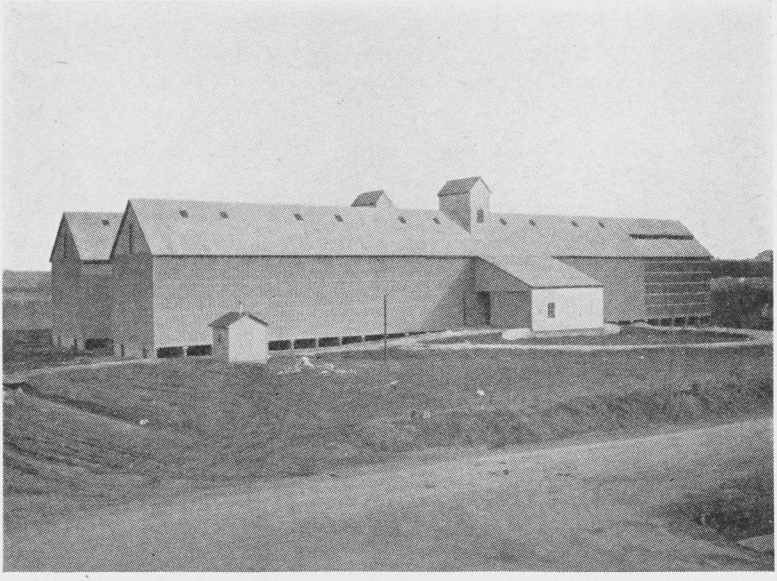

Fig. 7. A commercial popcorn storage crib which has a capacity of 9 million pounds of ear corn. One of the many large storage cribs which hold the commercial popcorn crop. Many such cribs are located in Sac, Ida and Crawford counties in west-central Iowa. These three counties produce 25 percent of the U. S. crop, over one-third of which is produced in Iowa.

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